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DOCUMENTATION OF DECISION-AIDING SOFTWARE:

INFER USERS MANUAL

DECISIONS AND DESIGNS INC.

Dorothy M. Amey
Phillip H. Feuerwerger
Roy M. Gulick

June 1979

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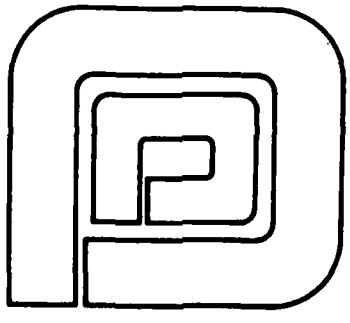
Dorothy M. Amey, Phillip H. Feuerwerger, and Roy M. Gulick

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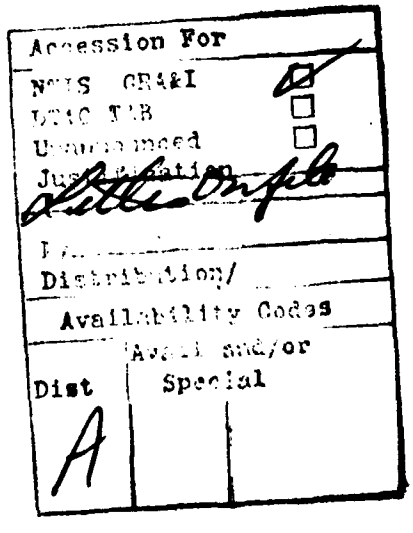
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INFER USERS MANUAL

1.0 INTRODUCTION

1.1 Purpose of the Users Manual

The purpose of this manual is to provide users of the INFER system with the background material and the detailed instructions necessary to use and interpret the various functions that INFER provides. The manual also presents the technical concepts inherent in the INFER approach, including various assumptions and restrictions concerning its use. The manual includes case study applications.

Because the manual must serve users both skilled and unskilled in the use of probability theory and decision-analytic methodology, it is prepared in a modular fashion. Thus, whereas the initial sections provide detailed information for the naive user, the last section is direct and unelaborated for those users knowledgeable in the approach.

1.2 References

1.2.1 Barclay, Scott, et al. Handbook for Decision Analysis. Technical Report 77-6-30. McLean, Virginia: Decisions and Designs, September 1977.

1.2.2 Gulick, Roy M. Documentation of Decision-Aiding Software: Introductory Guide. Technical Report TR 79-1-93. McLean, Virginia: Decisions and Designs, Inc., in press.

1.2.3 Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: INFER Functional Description. McLean, Virginia: Decisions and Designs, Inc., June 1979.

1.2.4 Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: INFER System Specification. McLean, Virginia: Decisions and Designs, Inc., April 1979.

1.2.5 Amey, Dorothy M.; Feuerwerger, Phillip H.; Gulick, Roy M. Documentation of Decision-Aiding Software: OPINT Users Manual. McLean, Virginia: Decisions and Designs, Inc., in press.

1.3 Terms

1.3.1 INFER - INFER is an abbreviation for inference, reflecting the logical process implemented by the system.

2.0 SYSTEM SUMMARY

2.1 Background

During crisis situations, military decision makers and their staffs strive to react swiftly, decide wisely, and communicate accurately. However, by its very definition, a crisis situation inherently creates significant obstacles to the successful attainment of those three worthwhile objectives.

Some of the obstacles occur because during a crisis decision makers must necessarily abandon their routine day-to-day working relationships, information channels, and standard, familiar procedures. Other obstacles arise from the increased tension and anxiety introduced by the enormity of the stakes at hand and the attendant risks, uncertainties, and intricate value trade-offs. Still other obstacles stem from the pressures of time constraints and the ambiguity of goals.

In particular, crisis decision making is usually attended by extraordinary demands for, and the production of, intelligence. Indeed, the tasks of intelligence collection, processing, and distribution may well dominate the decision-making process. Crisis decision makers are often inundated with a diverse collection of both hard, objective information and soft, subjective information, and both kinds may be of highly varying quality, importance, and relevance.

The high premium placed on the intelligence collection and processing task, coupled with the obstacles imposed by the crisis nature of the situation, greatly enhance the always-present opportunities for misperception, misunderstanding, and miscommunication among decision makers and

their staffs. To prevent those opportunities from arising, decision makers need effective decision-making strategies that impose rigor and provide a logical, structural framework to assist them in the process of choosing an optimal decision alternative in the face of voluminous and often inconclusive evidence.

INFER is a computer-aided strategy that provides just such a framework for deliberation, reasoning, and analysis. INFER aids decision makers by prescribing a straightforward normative procedure for organizing and analyzing the intelligence information concerning a key future event.

INFER has sound roots in probability theory, which dates from the 18th century, and decision analysis, a management discipline that emerged in the 1960's. As described in Reference 1.2.1, the discipline of decision analysis has proved enormously effective in aiding military decision-making processes across a broad spectrum of applications. The INFER approach, in particular, has been employed in many intelligence applications and in several actual crises, military exercises, and the development of contingency plans.

2.2 Objective

The overall objective of INFER is to ensure that the decision maker's considered and expressed beliefs about the outcomes of a future uncertain event are realistic and wholly consistent with the state of available information pertaining to the unfolding of that event.

INFER aids decision makers by providing them a capability to construct, store, retrieve, exercise, and refine inference models that characterize and appr ximate key

uncertain future events. Inference models serve as organizing frameworks for dealing logically and systematically with uncertainty and the information surrounding it.

The models assist the decision maker in processing the relevant objective and subjective information that influence the relative likelihoods of the various possible outcomes of a future event. INFER assists the decision maker by automating the model-building, model-manipulation, and model-storage and retrieval process.

It must be emphasized that the objective of INFER is not to replace experienced human judgment; rather, it serves as an accessory to the decision-making process: it aids human judgment. It is a strategy that aids in judging and systematically assessing the probabilities of future events based on dependence relationships.

The decision maker can incorporate the resultant probabilities into the selection of a course of action by using the OPINT system described in Reference 1.2.5.

2.3 Procedural Overview

The fundamental product of INFER is an inference model. The INFER system enables the user to create, store, retrieve, exercise, and revise inference models interactively.

All of the specific functions that INFER performs are related to the inference model. Therefore, to establish a frame of reference for the procedural overview, it is necessary to begin with a description of the general concept and format of an inference model.

2.3.1 Concept of an inference model - Consider a key future event, E, having several plausible outcomes. The nature of the problem addressed by INFER is to determine the relative likelihoods of all of the possible outcomes: E_1, E_2,...E_n.

There is but one standard measure for expressing the degree of uncertainty about a future event: probability. A probability is a number between 0 and 1, inclusive, that represents the extent to which a well-informed individual believes that a future event will occur. Hence, the problem is to determine values for $P(E_i)$, the probability of the i^{th} outcome of event E, for all i. INFER assists the user in deriving event outcome probabilities that are coherent, that is, consistent with the user's state of knowledge concerning future events as well as consistent with the laws of probability theory.

A key assumption in the use of INFER is that the unaided, direct assessment of the outcome probabilities is either impracticable or inadvisable because of their intricate dependencies on the outcomes of other preceding events. For example, assume that $P(E_i)$ is related to the outcomes of three preceding events: A, B, and C. Figure 2-1 illustrates one possible relationship among the key event, E, and the three other events. Each of the four events has, of course, several possible outcomes: A_l, B_k, C_j, E_i. An inference model seeks to capture the dependencies among these events and their outcomes.

2.3.2 Influence diagrams - The diagram in Figure 2-1 is called an influence diagram, since it pictorially represents the manner in which each of the events influences the other. An arrow indicates that one event directly influences another, the direction of the arrow indicating the direction

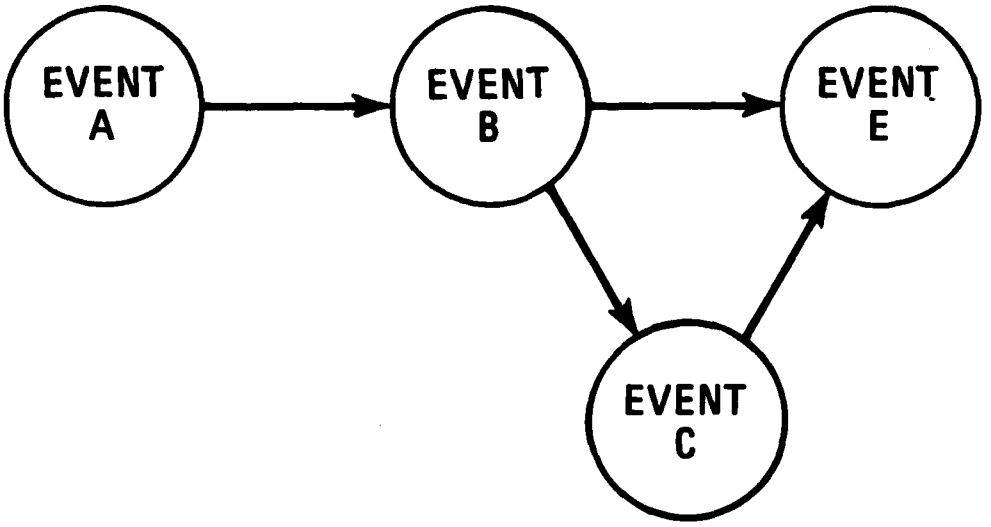


Figure 2-1
AN INFLUENCE DIAGRAM

of the influence. The absence of an arrow between any two events indicates their relative independence. For example, Figure 2-1 indicates that the outcome of Event E is independent of the outcome of Event A, and that the outcome of Event E depends only on the joint outcomes of Events B and C.

The probabilities of the various event outcomes may also be influenced by certain evidence, or key indicators, that may be observed in the future. Over time, the indicators will occur or not. The influence diagram shown in Figure 2-2, which is a revision of the previous influence diagram, contains an indicator, X. The diagram now shows that if Indicator X should occur in the future, then $P(C_j)$, the probabilities of the outcomes of Event C, must be changed accordingly.

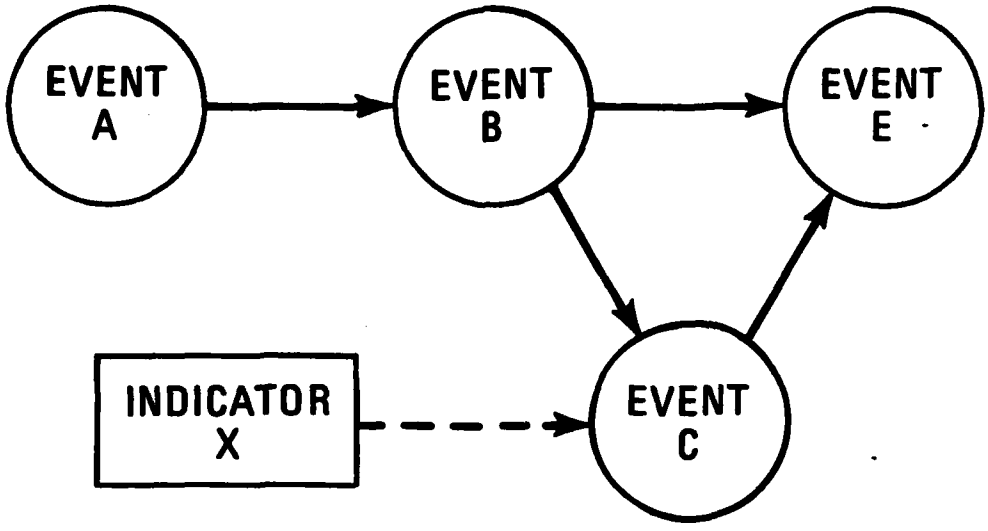


Figure 2-2

INFLUENCE DIAGRAM REVISED TO INCLUDE AN INDICATOR

2.3.3 Event nodes - An influence diagram, hence inference model, consists of indicators and event nodes. Indicators are discussed in the following section.

There are two different types of event nodes: conditioned and unconditioned.

Unconditioned event nodes represent events that are not influenced by any other event, hence they have no arrows directed toward them. The presumption is that the probabilities of their outcomes can be assessed directly. Event node A in Figure 2-2 is the only unconditioned event node shown. However, there may be more than one unconditioned event node in an influence diagram.

Conditioned event nodes represent events that are directly influenced by one or two other events; hence,

they have arrows directed toward them. Nodes B, C, and E in Figure 2-2 are all conditioned event nodes, of which there are two types: intermediate and terminal.

An influence diagram must contain only one terminal event node: the key event of interest. Event E in Figure 2-2 is the terminal event node. Note that Event E does not influence any other event.

Event nodes B and C in the figure are intermediate event nodes. They both influence other events, as well as being influenced themselves.

In order to completely specify an inference model, the user must specify: (1) the directly assessed probabilities of the outcomes of the unconditioned events; and (2) the conditional probabilities of the outcomes of the conditioned events. For example, in Figure 2-2, one must specify $P(A_1)$ and the following conditional probability matrices:

$P(B_k|A_1)$ -- the probability that Event B_k occurs, given that A_1 has occurred for all 1 and k;

$P(C_j|B_k)$ -- the probability that Event C_j occurs, given that B_k has occurred for all k and j;

$P(E_i|B_k,C_j)$ -- the probability that Event E_i occurs, given that the two Events B_k and C_j have both occurred for all j, k, and i.

2.3.4 Indicators--the effect of new information - For any event, INFER permits the user to incorporate into the model the impact that new information would have on the event outcome probabilities derived prior to observation of the new information. The underlying process is called Bayesian updating, i.e., calculating posterior probabilities based on the prior probabilities and the conditional probabilities that the information would be observed given that each particular event outcome did, in fact, occur.

For all of the possible outcomes of Event C, the user must assess and specify an ordered vector, L_j, in which the least likely outcome for observing the indicator is assigned a value of 1, and each other outcome is assigned a value corresponding to the number of times that outcome is more likely to occur than is the least likely outcome. For example, assuming that Event C has three possible outcomes, the likelihood vector 3 1 6 would indicate that Indicator X is three times as likely to be observed if C_1 has occurred than C_2, and twice as likely if C_3 has occurred than C_1.

2.3.5 Applying inference models - The user who is inexperienced in probability theory and decision analysis is cautioned that the models should not be applied indiscriminately, nor their results interpreted blindly. In particular, the prospective user must understand that the INFER framework fits only those specialized situations that meet all of the following characteristics:

- The intelligence problem is well formed; i.e., key uncertainties, their plausible outcomes, and their dependencies have been identified.

- A simple structural representation of the problem will suffice.

- The decision maker is working under a short time constraint.

- Direct assessment of the key uncertain event outcome probabilities is impracticable or inadvisable.

- An ad hoc analysis is appropriate.

3.0 STRUCTURING THE INFER MODEL

To use the INFER software, the user must first create an INFER model. To facilitate understanding of the model-creation process, this section uses a case study approach. Consider the following hypothetical scenario.

3.1 Hypothetical Crisis

The Premier of Rambo, a tiny island country, is a charismatic but fanatical leader who has denounced the U.S. endlessly for years. However, the pace and intensity of his accusations have increased markedly during the past three weeks.

Early this morning he issued a lengthy, emotional, and bizarre world-wide proclamation accusing the U.S. of recent deprivations and provocations, including destruction of Rambo's economy, terrorist attacks, and an attempted assassination directed at him. He threatened armed retaliation and mentioned "Soviet support" and a "virtual rainbow of missiles from Rambo to U.S. bases and aircraft."

His proclamation has incited the Rambo citizens to a fever pitch. The government-controlled Rambo press is calling for a show of force. Volunteer reserve units of the Rambo navy have spontaneously begun to report to the small naval base at El Freba.

The U.S. National Command Authority (NCA) believes that there is a clear and present danger: if Rambo obtains missiles, they will be used against U.S. aircraft and bases. A two-month-old intelligence estimate indicates a 1% probability that Rambo has missiles. In order to choose an

appropriate course of action, the NCA has asked for updated intelligence estimates regarding the likelihood that missiles have been introduced into Rambo.

Assume that an intelligence analyst has decided to use INFER, and hence an inference model, to assist in the preparation of the intelligence estimates.

3.2 Inference Model

Each inference model created by the user is based on an influence diagram, as discussed in Section 2.3.3. Ideally, the influence diagram has been developed by the user prior to using the INFER system. Figure 3-1 is an influence diagram for the Rambo crisis.

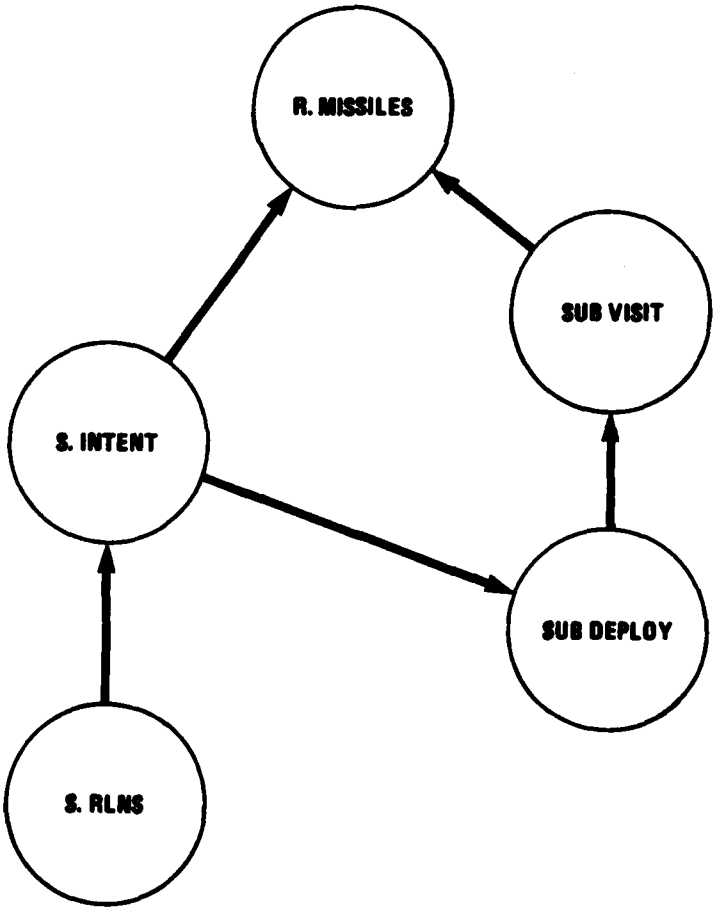


Figure 3-1
RAMBO INFLUENCE DIAGRAM

The inference model format, which is based on the influence diagram, always consists of the following elements of information which, when they are completely specified, uniquely define an INFER inference model.

3.2.1 The terminal event - A label defining the key event of interest. The label also identifies the inference model for future storage and retrieval.

In the Rambo situation, the key uncertainty is the presence of missiles in Rambo. An appropriate label for the key event would be: MISSILES. (Assume that there are two possible outcomes for the terminal event: missiles present, and no missiles.)

3.2.2 Conditioning events - A list of the one or two events whose outcomes condition, or directly influence, the terminal event.

The user must identify those other future events whose outcomes would influence the outcome of the terminal event. In the Rambo situation, two events are so judged: Soviet intent to support Rambo by delivering the missiles, and a physical means for accomplishing the delivery. Furthermore, the analyst has concluded, for several unassailable reasons, that the only possible means for delivery is by a surreptitious visit to El Freba by a Soviet ballistic-missile submarine. Appropriate labels for the two conditioning events might be: S. INTENT and SUB VISIT.

3.2.3 Remaining events - For all of the remaining (non-terminal) events, a list of the one or two events whose outcomes condition (influence) them. If no conditioning events are specified, the event is assumed to be an unconditioned event.

For each remaining event, the user must identify other events whose outcomes influence the former. For example, the uncertainty surrounding Soviet intent may be influenced by Soviet relationships with the U.S. (S-REL). The uncertainty surrounding a surreptitious submarine visit may be influenced by a change in Soviet submarine deployments (SUB. DEPLOY).

Continuing the chain of influence, the analyst concludes that the current Soviet relationship with the U.S. can be directly assessed, and that a change in Soviet submarine deployment would be influenced by Soviet intent to deliver the missiles, an event previously specified.

3.2.4 Event outcomes - For each event, a list of the discrete event outcomes, each appropriately labeled, that together define the universe of possibilities regarding the eventual unfolding of the event.

Several guidelines pertain to the creation of that list.

a. The list should be exhaustive. That is, it should include all of the event outcomes that are under serious consideration. A key assumption here is that one of the outcomes on the list will in fact occur. In that regard, note that the outcome "other" is a perfectly legitimate alternative for inclusion on the list.

b. The list should also be exclusive; that is, the outcomes should be independent. The occurrence of one outcome should preclude the implied occurrence

of another. This restriction, together with the previous one, ensures that one and only one of the outcomes on the list will ultimately occur.

c. The outcomes on the list should be reasonable ones. The list should not include any outcomes that are impossible.

d. Similar outcomes should be combined where possible in order to reduce the total number to a reasonable length. Ten outcomes is an upper bound; two to five are preferred.

Figure 3-2 illustrates the structure of the model as specified to this point.

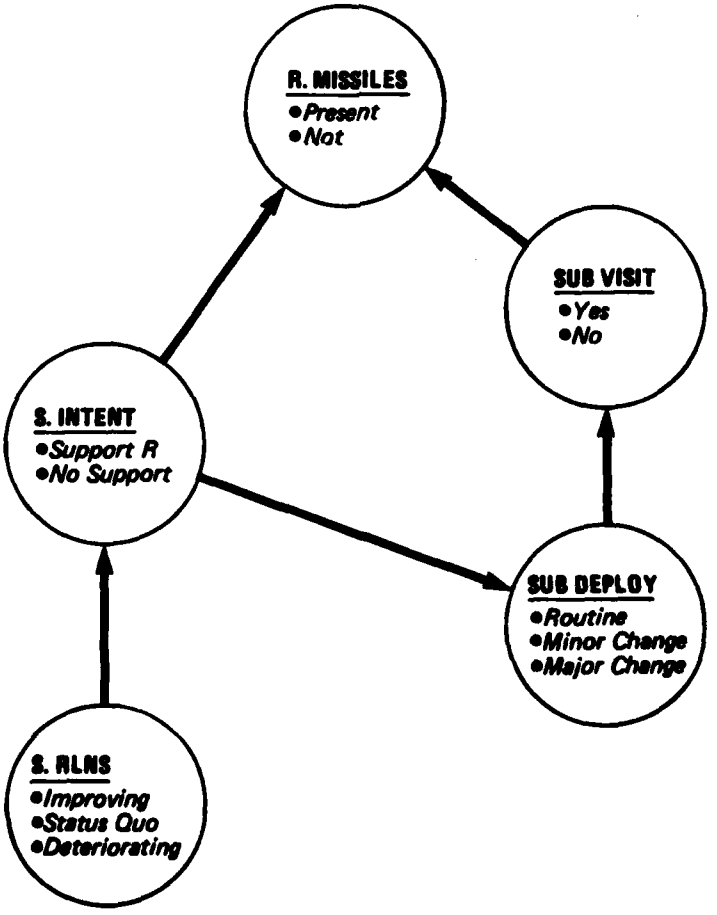


Figure 3-2
REVISED RAMBO INFLUENCE DIAGRAM

3.2.5 Unconditioned event outcome probabilities - For each unconditioned event, a vector of event outcome probabilities.

In the Rambo case, the only unconditioned event is Soviet Relations (S. RLNS). Based on current information, the analyst might assign the following probabilities:

S. RLNS	PROBABILITY (%)
IMPROVING	10
STATUS QUO	70
DETERIORATING	20

3.2.6 Conditioned event outcome probabilities - For each conditioned event, a matrix of conditional probabilities for the event outcomes. Conditional probabilities are based on the assumption that one of the conditioning event outcomes has occurred.

For example, submarine deployment (SUB DEPLOY) is conditioned by Soviet intent (S. INTENT). The following matrix pertains, and is elicited row by row, first assuming that there is an intent to support Rambo, and then assuming that there is no such intent. Note that the row probabilities must sum to 100%.

	SUB DEPLOY		
	ROUTINE	MINOR CHANGE	MAJOR CHANGE
S. INTENT			
SUPPORT R.	60	35	5
NO SUPPORT	95	5	0

Figure 3-3
PROBABILITY (%) OF SUBMARINE DEPLOYMENT
GIVEN SOVIET INTENT

Similar matrices are prepared for the events SUB VISIT and S. INTENT.

Since the terminal event is influenced by two preceding events, its conditional probability matrix is based on the assumed occurrence of the joint events, S. INTENT and SUB VISIT, as shown in Figure 3-4.

		R. MISSILES	
S. INTENT •	SUB VISIT	PRESENT	NOT
SUPPORT R	YES	95	5
SUPPORT R	NO	1	99
NO SUPPORT	YES	20	80
NO SUPPORT	NO	1	99

Figure 3-4
PROBABILITY (%) OF RAMBO MISSILES
GIVEN SOVIET INTENT AND SUB VISIT

3.2.7 Indicators - For each event affected by an indicator, the name of the indicator and the associated likelihood vector, as described in Section 2.3.4. Furthermore, indicators must be specified as being either on (observed) or off (not observed).

In the Rambo case, two indicators are appropriate, as shown in Figure 3-5. In the case of the unexpected detection of a Soviet submarine, assume that the analyst assigns a likelihood vector 1 4 8, indicating that the indicator would be four times more likely to be observed if there were a minor change in submarine deployments than if deployments were routine, and eight times more likely if there were a major change.

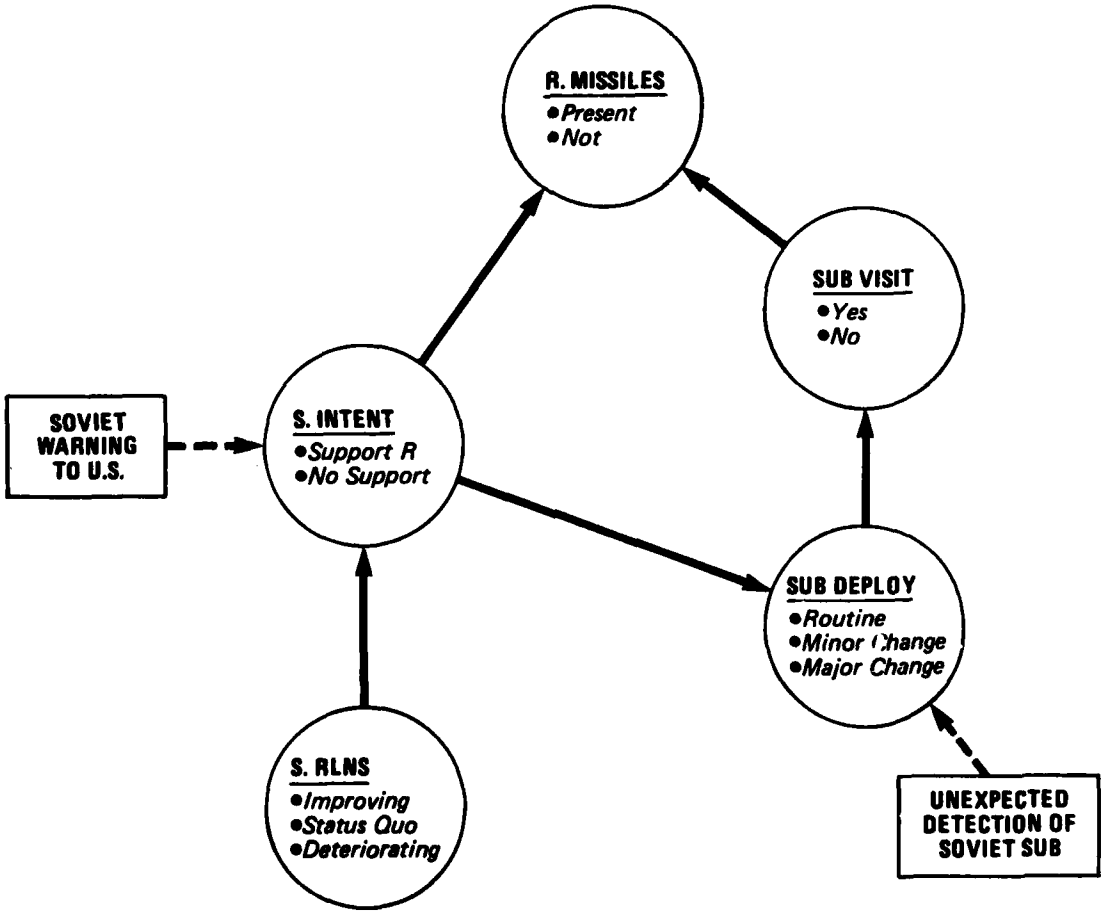


Figure 3-5

RAMBO INFLUENCE DIAGRAM WITH INDICATORS

This completes the model format. The inference model is completely and uniquely specified when the elements described above are defined by the user.

3.3 Purpose of the Model

At this point it must be noted that the purpose of an INFER model is not to capture reality, but rather to provide a reasonable surrogate for it. Structuring an INFER model is an art, and the practice of that art is attended by great difficulties in selecting a representative set of uncertain events, event outcomes, indicators, and dependency relationships. Ideally, a professional decision analyst would work closely with the user in structuring the influence diagram and developing an influence model. In any case, the ultimate tests of an inference model should be:

a. Does the model approximate the reality of the situation?

b. Is the model free of obvious inconsistencies with the information at hand?

c. Is the model consistent with the laws of probability theory?

d. Does the model provide insight into the intelligence problem?

e. Is the model practical and useful to the user?

4.0 RESULTS OF THE MODEL

The input specifications described in the previous section can be processed to produce the event outcome probabilities of the terminal event and any other event of interest. The resulting outcome probabilities are referred to as marginal probabilities.

The user can display the following:

a. For the terminal event only, the name of the event, the names of the possible event outcomes, and the computed event outcome probabilities (expressed as percentages), as shown in Figure 4-1.

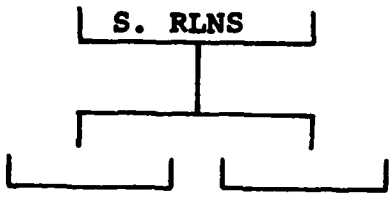
	PRESENT	NOT
R. MISSILES	41	59

Figure 4-1
LIKELIHOOD OF R. MISSILES

b. For any selected event, the following items as shown in Figure 4-2:

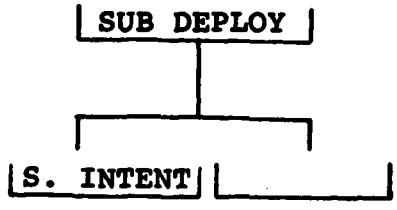
   - an influence diagram indicating the name of the selected event and the names of the one or two events that condition it (if any); and

- a matrix containing the conditional event outcome probabilities (if there are conditioning events), the calculated (or directly assessed) probabilities of the conditioning event outcomes, and the calculated marginal (or directly assessed) probabilities of the selected event outcomes.



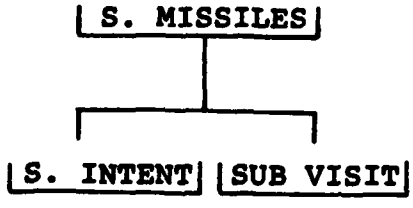
	-- S. RLNS --		
	IMPROVING	STATUS QUO	DETERIORATING
PROBABILITY	10	70	20

a. DIRECTLY ASSESSED EVENT



		-- SUB DEPLOY --		
S. INTENT		ROUTINE	MINOR CHANGE	MAJOR CHANGE
SUPPORT R.	(35)	60	35	5
NO SUPPORT	(65)	95	5	0
MARGINAL PROBABILITY		82	16	2

b. EVENT CONDITIONED BY ONE OTHER EVENT



		-- S. MISSILES --	
S. INTENT/SUB VISIT		PRESENT	NOT
SUPPORT R./YES	(26)	95	5
SUPPORT R./NO	(6)	1	99
NO SUPPORT/YES	(38)	20	80
NO SUPPORT/NO	(9)	1	99
MARGINAL PROBABILITY		32	68

c. EVENT CONDITIONED BY TWO OTHER EVENTS

Figure 4-2
THREE INFLUENCE DIAGRAMS

5.0 TECHNICAL OPERATIONS

This section explains in detail how a user interfaces with the INFER software. It is assumed that an INFER model exists in conceptual form.

When the INFER program has been loaded into the computer and the program started, a menu of options will be displayed to the user.

5.1 Option Menus

INFER is hierarchically structured and menu-driven. At each level of the hierarchy, a menu of options is displayed to the user. Selection of any particular option will either cause an operation to be performed directly, or it will result in the display of a new menu. If another menu appears and the user subsequently wishes to return to the starting point, the user need only return the carriage without choosing any specific option. With few exceptions, returning the carriage at any time (without inputting other instructions or making selections) will cause the computer to display the next higher menu in the hierarchy. If the menu displayed is the one at the top of the hierarchy, returning the carriage will result in a query to the user regarding termination of the program.

For example, suppose the user begins with the primary (i.e., highest level) menu (discussed more fully in the next section) containing the following options:

- create new model;
- display results;

- display inference model;
- edit the model;
- reset indicators;
- load model; and
- save model.

Selecting "Edit Diagram" and returning the carriage causes a new menu, which requests more information, to appear. Thus, selecting the "Edit Diagram" option requires the user to specify in more detail the part of the diagram to be edited, accomplished by selecting one of the new options appearing in the secondary menu. If, however, instead of selecting one of these options, the user simply returns the carriage, the program will return to the primary menu.

5.2 The Primary Menu

After the user has loaded the INFER program into the computer, the primary menu will be displayed. This menu includes seven options:

- create new model;
- display results;
- display inference model;
- edit the model;
- reset indicators;

- o save model; and
- o load model.

This display is the principal menu and provides entry to a variety of secondary menus. Each of the primary options and the options in the secondary menus are discussed in the sections which follow.

5.2.1 Create new model - This option allows the user to create an altogether new model, including assessment of all values required. To begin use of the INFER program, the user must either load an old (existing) model or create a new one. If the user prefers to create a new model rather than to work with an existing one, this option should be selected. As this option requires considerable explanation, Section 5.3 has been devoted entirely to it.

5.2.2 Display results - This option allows the user to display the conditioned probability of each of the possible outcomes of the terminal event based on assessments made during construction of the model. These probabilities are the chief results sought in using the system.

5.2.3 Display inference model - Selection of this option will cause another menu of options to be displayed, requesting the user to specify an event to be displayed. Upon specification of an event, that event and the immediate events upon which it is conditioned are displayed. When the user next returns the carriage, the probabilities of the possible outcomes of the specified event are displayed, as are the assessed conditional probability matrix and the computed (or directly specified) probabilities of the outcomes of the conditioning events. Returning the carriage again allows the user to select another conditioning event for display, if desired.

5.2.4 Edit the model - Selection of this option allows the user either to edit the assessed probabilities of conditioning events or to turn on, turn off, or add new indicators. When "Edit the Model" is selected, a secondary menu appears containing the options "Edit the Diagram" and "Edit Indicators." They are explained below.

Edit the diagram. Selecting this option allows the user to change the assessed conditional probability matrix, that is, the probabilities of the outcomes of any specific event given the outcome of conditioning events. The system will ask the user to specify which event requires editing. After the user specifies the event, the system will accept changes to the assessments of the conditional probabilities. After all editing is completed, the system will recalculate the conditioned probability of each possible outcome of the key uncertainty.

Edit indicators. Selecting this option presents the user another menu containing the choices "Change Likelihoods" and "Add Indicators." If "Change Likelihoods" is selected, the user is presented with a menu of all indicators. After one is specified, the user is allowed to change the assessment of the likelihood vector for that indicator. If "Add Indicators" is selected, the user is asked to specify the event node to which the new indicator applies, followed by the name of the indicator and the likelihood vector.

5.2.5 Reset indicators - This option permits the user to "turn on" or "turn off" existing indicators. This permits the user to update probability estimates automatically by activating or deactivating indicators. As the indicators are turned on to signify the occurrence of various events, the computer updates the calculation of the conditioned probabilities of each possible outcome of the key uncertainty by using the technique known as "Bayesian updating."

5.2.6 Load model - Selection of this option causes the computer to inform the user of the existing models available for loading into the system. A user may wish to load an old model in order to display an existing analysis, to modify a model, or to update data stored in the system. The titles of the various available models were previously assigned by using the "Save Model" option. Selecting a specific model causes the system to load that model into the workspace.

5.2.7 Save model - This option provides the user a means of storing a model for later use. In using the "Save Model" option, it is necessary that the user specify a model name, which can be either a new one or the same name as an existing model. In the case of a new name, the model will be stored under that name, and the name will automatically be added to the list of models available. If, instead, the user specifies the name of an existing model, the model currently stored under that name will be replaced by the new model and the old model will be lost. This would normally be done when corrections have been made to an existing model.

5.3 Create New Model

When the user selects this option, the system will request the various items required to construct an entirely new model. The system will first instruct the user to input the name of the terminal event. The system will then ask what other events directly influence the key event (the user is limited to two influencing events). The system continues by requesting the names of those events which influence the intermediate event.

The system continues to request the names of conditioning events until the user acts as follows: If only one new event influences any specific event, the user should

type in that event when requested. When the computer requests the second influencing event, the user should return the carriage without typing anything. Similarly, if the user is able to assess the probability of any specific event directly (and, therefore, does not wish to specify any particular events on which it is conditioned), the user should return the carriage without typing anything when asked for the first influencing event. Eventually, the user will have specified that the probability of every event is conditioned on the outcome of one or two other events or that it can be assessed directly. At that time, the structure of the model has been specified.

One additional detail should be mentioned. If the outcome of a single event influences the probabilities of two other events, the user must be sure to type the exact same name of the influencing event in both cases. For similar reasons, the user should also remember not to give exactly the same name to two different events. Otherwise, the computer will treat the distinct events as a single event.

After the user has completely outlined the influence structure, the system will request the names of the possible outcomes of each event. The system will begin with the unconditioned events, that is, those which do not depend on any other events. The user types in the names of the possible outcomes, one per line, returning the carriage without typing anything when the final event outcome has been input. The system then will instruct the user to type in the relative probabilities of each outcome. After the user has done this, the computer will normalize the assessed probabilities to sum to 100%, and request confirmation. The system will repeat this process for each unconditioned event.

After the user has assessed the probabilities of every unconditioned event, the system will request the name of the

possible outcomes of the conditioned events. After the user has typed in the outcome names, the system will ask the user to input the conditional probabilities of the possible outcomes, assuming each possible outcome of the events on which it is conditioned. The computer then normalizes the probabilities and requests confirmation. This continues until the user has assessed all of the relevant conditional probabilities/matrices.

The system then asks the user whether the model includes any indicators. Indicators are events which, if they occur, markedly affect the likelihood of some single event in the model. Bayesian updating is used to modify the probability of that event if the indicator is activated during the utilization of the model.

If the user responds that the model contains indicators, the computer requests the name of the first indicator. After the user types the name in, the computer asks the user to specify which event the indicator affects directly. The user is then asked to give the likelihood vector, as discussed in Section 2.3.4. After the user has typed these in, the system requests confirmation and asks if the model contains any more indicators. If so, the user responds by typing "YES" and the computer repeats the steps necessary to specify an additional indicator. If not, the user types "NO" and returns the carriage.

At this point, the system will display the conditioned probabilities of the possible outcomes of the terminal event. The system then asks whether the user wishes to see a display of the influence diagram. If the user answers positively, the system reacts in the same manner as it would were the "Display Inference Model" option chosen from the primary menu. If the user responds negatively, the system returns to the primary menu for further instructions.

6.0 AN EXAMPLE OF THE USE OF THE INFER SYSTEM

This chapter presents an example of an analysis which might be undertaken using the INFER system. It contains the essential elements necessary to make the use of INFER ideal: a key uncertain event with several possible outcomes, the probabilities of which cannot be assessed directly but which can be described in terms of a set of influencing events, each of which is directly assessable.

6.1 A Force Posturing Example

This example concerns the probability assessments required before reaching a decision about committing U.S. forces to a particular posture. It involves the assessment of the probability of various subsidiary events upon which the key uncertainty is dependent. The uncertainty concerns the possible types of evacuations required from Lebanon during a crucial period in the recent civil war.

6.1.1 Background - In the example, fighting has broken out in the Middle East and U.S. military forces in Europe may be asked to evacuate U.S. nationals from the area. There are a number of posturing actions that the staff would like to analyze in anticipation of a worsening situation. As part of their analysis, the analysts must first assess the probability that an evacuation will become necessary and, if so, the likely size of the evacuation.

The possible outcomes the staff considered varied from a situation in which a small number of American citizens might become concerned about their safety and wish to return to the U.S. to a much worse situation in which it would become necessary to evacuate about 6,000 Americans and

allied personnel during heavy fighting. The specific outcomes of the key uncertainty considered were:

- o No evacuation is necessary because a ceasefire agreement had been negotiated (NONE).

- o The fighting continues, commercial airlines cancel flights into the area, and a small number (300) of personnel wish to leave the country in a permissive situation. Friendly security forces control the airport and access routes from Beirut (P-300).

- o The fighting continues, commercial airlines cancel flights into the area, and a large number (2,000) of personnel wish to leave the country in a permissive situation. Friendly security forces control the airport and access routes from Beirut (P-2K).

- o Fighting increases in Beirut, and most (2,000) of the U.S. nationals living in the immediate area want to leave in a non-permissive situation. The airport is subjected to sporadic gunfire; therefore, armed helicopters and security forces may be required (NP-2K).

- o Heavy fighting spreads throughout the country, and up to 6,000 U.S. and allied nationals may want to leave in a non-permissive situation. The evacuation force must be prepared to operate in a warlike environment (NP-6K).

In the above description, "P" and "NP" indicate Permissive and Non-Permissive evacuation, and 300, 2K (2,000), and 6K (6,000) indicate the size of the necessary evacuation.

Because the probabilities of these outcomes could not be assessed directly, they were made conditional on the outcome of the future level of hostilities and the possible intervention by Israeli forces. The relevant influence diagram is shown in Figure 6-1. The possible outcomes of hostilities were: decreased, status quo, increased in and around Beirut, and increased country-wide. The possible outcomes of Israeli action were invasion or no invasion. Hostilities were thought to depend on the outcome of elections (with possible outcomes of elections occurring with a pro-Syrian result [Yes +S], elections occurring with an anti-Syrian result [Yes -S], elections not occurring because of some Syrian action [No/S], and elections not occurring because of some action by the Palestinian Liberation Organization [No/P]). Israeli action was thought to depend on the level of Syrian intervention (main force to the North or South of the Litani River). Finally, the likelihood of Syrian action was expected to depend on the level of hostilities, as shown in Figure 6-1.

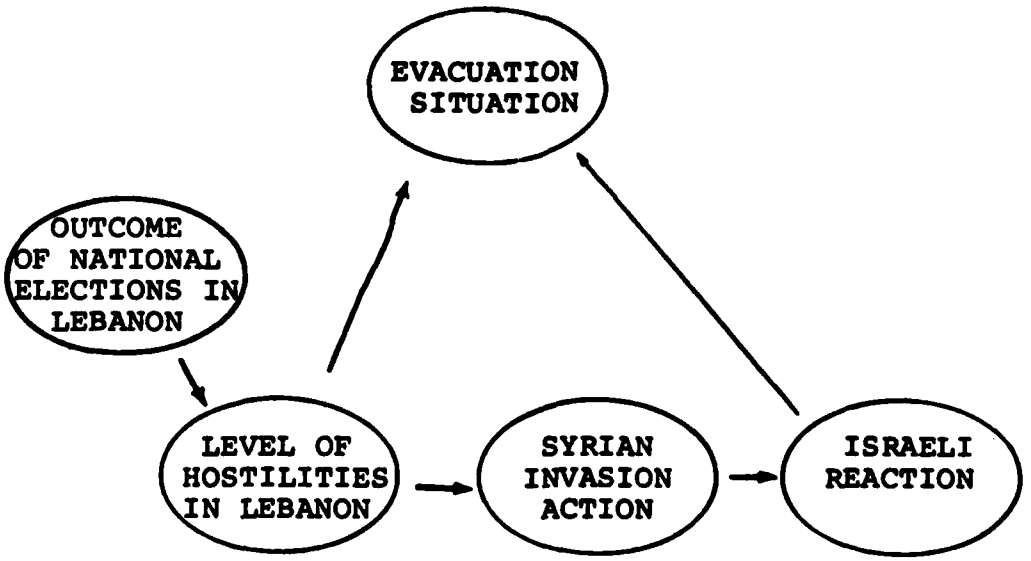


Figure 6-1
THE INFLUENCE DIAGRAM

Other events which belong in the model as "indicators" can be activated or deactivated at the user's command. An Israeli threat to intervene would alter the assessed probability of an Israeli act of intervention. A warning by Syria would increase the probability of Syrian movements south of the Litani River. Were an election actually planned, the probability of one taking place would increase. Should the PLO issue a warning, the probability of it disrupting elections would increase. Finally, were external fighting to occur elsewhere in the Middle East, the probability of hostilities spreading would increase.

Other possible events investigated during the model's construction but considered unlikely to occur included Libyan intervention, Iraqi intervention, and direct Soviet support for the anti-Christian forces. If, at a later time, information became available concerning any of these contingencies, the analysis could be reconstructed to include them as either indicators of influencing events.

6.1.2 Using the INFER software to structure the example problem - In this section, the above example will be structured by using INFER. The figures which appear are representations of possible input and output formats. Other data formats incorporating the same type of information would be equally suitable.

The first step the user must perform is to load the INFER program. A menu of options, as shown in Figure 3-2, will be displayed. In this and all succeeding figures, user inputs are underlined to distinguish them from system instructions.

```
SELECT THE NUMBER OF THE OPTION YOU DESIRE
     1)   CREATE NEW MODEL
     2)   DISPLAY RESULTS
     3)   DISPLAY INFERENCE MODEL
     4)   EDIT DIAGRAM
     5)   RESET INDICATORS
     6)   SAVE MODEL
     7)   LOAD MODEL
SELECTION: 1
```

Figure 6-2
THE PRIMARY MENU

Selecting "Create New Model" places the program in the structuring mode and the system will ask the user for the name of the terminal event, the key uncertainty. The system then requests confirmation. Figure 6-3 shows one possible format for this user-computer interchange.

```
ENTER THE NAME OF THE EVENT OF INTEREST
PLEASE LIMIT THE NAME TO 10 CHARACTERS.
     1)   EVACUATION
THE LABELS YOU HAVE ENTERED ARE:
     1 - EVACUATION
IF THESE ARE CORRECT TYPE GO: GO
```

Figure 6-3
DESIGNATING THE EVENT OF INTEREST

The system then instructs the user to type in the names of the events that directly influence the key uncertainty. After the user has typed these in, the system

will request the names of events influencing these second-level events. This continues with each new event that the user names. (If the user can directly assess the probabilities of the various outcomes of any event, the carriage is returned without specifying any conditioning events.) Figure 6-4 illustrates this process.

```
ENTER THE NAMES OF THE EVENTS INFLUENCING "EVACUATION,"
ONE PER LINE, LIMITED TO 10 CHARACTERS.
     1)   HOSTILITYS
     2)   ISRAEL ACT

THE LABELS YOU HAVE ENTERED ARE:
     1 - HOSTILITYS
     2 - ISRAEL ACT
IF THESE ARE CORRECT TYPE GO:  GO

ENTER THE NAMES OF THE EVENTS INFLUENCING "HOSTILITYS,"
ONE PER LINE, LIMITED TO 10 CHARACTERS.
     1)   ELECTIONS
     2)

THE LABELS YOU HAVE ENTERED ARE:
     1 - ELECTIONS
IF THESE ARE CORRECT TYPE GO:  GO

ENTER THE NAMES OF THE EVENTS INFLUENCING "ISRAEL ACT,"
ONE PER LINE, LIMITED TO 10 CHARACTERS.
     1)   SYRIA
     2)

THE LABELS YOU HAVE ENTERED ARE:
     1 - SYRIA
IF THESE ARE CORRECT TYPE GO:  GO

ENTER THE NAMES OF THE EVENTS INFLUENCING "ELECTIONS,"
ONE PER LINE, LIMITED TO 10 CHARACTERS.
     1)   HOSTILITYS
     2)

ENTER THE NAMES OF THE EVENTS INFLUENCING "SYRIA,"
ONE PER LINE, LIMITED TO 10 CHARACTERS.
     1)   HOSTILITYS
     2)

THE LABELS YOU HAVE ENTERED ARE:
     1 - HOSTILITYS
IF THESE ARE CORRECT TYPE GO:  GO
```

Figure 6-4
DESIGNATING THE INFLUENCE DIAGRAM

The system will next request the names of the possible outcomes of the various events and the probabilities of these outcomes conditioned on the influencing events. The system will normalize these and display the results for confirmation. The following pages illustrate the process.

```
ENTER THE NAMES OF THE POSSIBLE OUTCOMES OF "ELECTIONS,"
ONE PER LINE, LIMITED TO 5 CHARACTERS.
     1)   YES+S
     2)   YES-S
     3)   NO/S
     4)   NO/P
     5)

THE LABELS YOU HAVE ENTERED ARE:
     1 - YES+S
     2 - YES-S
     3 - NO/S
     4 - NO/P
IF THESE ARE CORRECT TYPE GO:  GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF ELECTIONS
            YES+S       YES-S       NO/S      NO/P
              4           1           2         3
NORMALIZED:  40          10          20        30
IF THESE ARE CORRECT TYPE GO:  GO

ENTER THE NAMES OF THE POSSIBLE OUTCOMES OF "HOSTILITYS,"
ONE PER LINE, LIMITED TO 5 CHARACTERS.
     1)   DECR
     2)   SQ
     3)   BEIRT
     4)   CNTRY
     5)
```

THE LABELS YOU HAVE ENTERED ARE:

1 - DECR
2 - SQ
3 - BEIRT
4 - CNTRY

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF HOSTILITYS ASSUMING "YES+S" FOR ELECTIONS:

	DECR	SQ	BEIRT	CNTRY
	3	2	3	2
NORMALIZED:	30	20	30	20

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF HOSTILITYS ASSUMING "YES-S" FOR ELECTIONS:

	DECR	SQ	BEIRT	CNTRY
	2	3	2	3
NORMALIZED:	20	30	20	30

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF HOSTILITYS ASSUMING "NO/S" FOR ELECTIONS:

	DECR	SQ	BEIRT	CNTRY
	1	5	8	6
NORMALIZED:	5	25	40	30

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF HOSTILITYS ASSUMING "NO/P" FOR ELECTIONS:

	DECR	SQ	BEIRT	CNTRY
	1	4	7	8
NORMALIZED:	5	20	35	40

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE NAMES OF THE POSSIBLE OUTCOMES OF "SYRIA,"
ONE PER LINE, LIMITED TO 5 CHARACTERS.

1) NORTH
2) SOUTH
3)

THE LABELS YOU HAVE ENTERED ARE:

1 - NORTH
2 - SOUTH

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF SYRIA
ASSUMING "DECR" FOR HOSTILITYS:

	NORTH	SOUTH
	19	1
NORMALIZED:	95	5

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF SYRIA
ASSUMING "SQ" FOR HOSTILITYS:

	NORTH	SOUTH
	19	1
NORMALIZED:	95	5

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF SYRIA
ASSUMING "BEIRT" FOR HOSTILITYS:

	NORTH	SOUTH
	19	1
NORMALIZED:	95	5

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF SYRIA ASSUMING "CNTRY" FOR HOSTILITYS:

	NORTH	SOUTH
	17	3
NORMALIZED:	85	15

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE NAMES OF THE POSSIBLE OUTCOMES OF "ISRAEL ACT," ONE PER LINE, LIMITED TO 5 CHARACTERS.

1) INVAD
2) NOINV
3)

THE LABELS YOU HAVE ENTERED ARE:

1 - INVAD
2 - NOINV

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF ISRAEL ACT ASSUMING "NORTH" FOR SYRIA:

	INVAD	NOINV
	1	9
NORMALIZED:	10	90

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF ISRAEL ACT ASSUMING "SOUTH" FOR SYRIA:

	INVAD	NOINV
	9	1
NORMALIZED:	90	10

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE NAMES OF THE POSSIBLE OUTCOMES OF "EVACUATION,"
ONE PER LINE, LIMITED TO 5 CHARACTERS.

1) NONE
2) P-30
3) P-2K
4) NP-2K
5) NP-6K
6)

THE LABELS YOU HAVE ENTERED ARE:

1 - NONE
2 - P-300
3 - P-2K
4 - NP-2K
5 - NP-6K

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATIONS
ASSUMING "DECR" FOR HOSTILITYS
AND "INVAD" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	2	1	5	6	6
NORMALIZED	10	5	25	30	30

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATIONS
ASSUMING "DECR" FOR HOSTILITYS
AND "NOINV" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	1	0	0	0	0
NORMALIZED:	100	0	0	0	0

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATION
ASSUMING "SQ" FOR HOSTILITYS
AND "INVAD" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	2	1	5	6	6
NORMALIZED:	10	5	25	30	30

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATION
ASSUMING "SQ" FOR HOSTILITYS
AND "NOINV" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	80	5	5	10	0
NORMALIZED:	80	5	5	10	0

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATION
ASSUMING "BEIRT" FOR HOSTILITYS
AND "INVAD" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	1	0	2	8	9
NORMALIZED:	5	0	10	40	45

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATION
ASSUMING "BEIRT" FOR HOSTILITYS
AND "NOINV" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	10	1	4	3	2
NORMALIZED:	50	5	20	15	10

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATION
ASSUMING "CNTRY" FOR HOSTILITYS
AND "INVAD" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	1	0	2	8	9
NORMALIZED:	5	0	10	40	45

IF THESE ARE CORRECT TYPE GO: GO

ENTER THE PROBABILITIES OF THE POSSIBLE OUTCOMES OF EVACUATION
ASSUMING "CNTRY" FOR HOSTILITYS
AND "NOINV" FOR ISRAEL ACT:

	NONE	P-300	P-2K	NP-2K	NP-6K
	2	0	1	1	1
NORMALIZED:	40	0	20	20	20

IF THESE ARE CORRECT TYPE GO: GO

Now that the user has identified the outcomes and assessed the probabilities, the system asks whether the model includes any indicators. If so, the user must specify a name, the event which the indicator affects directly, and the likelihood vector for the indicator. If the user later activates the indicator, the system will use the likelihood vector to calculate an updated probability, using Bayesian updating. The following user-system interchange depicts a possible format for including indicators.

DO YOU WISH TO INCLUDE INDICATORS IN THE MODEL (YES OR NO)? YES
ENTER AN INDICATOR NAME, LIMITED TO 10 CHARACTERS: ISR THREAT
SELECT THE NUMBER OF THE EVENT WHICH "ISR THREAT" AFFECTS.

1) EVACUATION
2) HOSTILITYS
3) ISRAEL ACT
4) ELECTIONS
5) SYRIA

SELECTION: 3

ENTER THE LIKELIHOOD RATIO FOR THE OUTCOMES OF ISRAEL ACT AFTER ISR THREAT:

INVAD	NOINV
5	1

IF THESE ARE CORRECT TYPE GO: GO

ENTER AN INDICATOR NAME, LIMITED TO 10 CHARACTERS: SYR WARNS
SELECT THE NUMBER OF THE EVENT WHICH "SYR WARNS" AFFECTS.

1) EVACUATION
2) HOSTILITYS
3) ISRAEL ACT
4) ELECTIONS
5) SYRIA

SELECTION: 5
ENTER THE LIKELIHOOD RATIO FOR THE OUTCOMES OF SYRIA AFTER SYRIA WARNS:

NORTH	SOUTH
1	3

IF THESE ARE CORRECT TYPE GO: GO

ENTER AN INDICATOR NAME, LIMITED TO 10 CHARACTERS: ELEC PLAND
SELECT THE NUMBER OF THE EVENT WHICH "ELEC PLAND" AFFECTS:

1) EVACUATION
2) HOSTILITYS
3) ISRAEL ACT
4) ELECTIONS
5) SYRIA

SELECTION: 4
ENTER THE LIKELIHOOD RATIO FOR THE OUTCOMES OF ELECTIONS AFTER ELEC PLAND:

YES+S	YES-S	NO/S	NO/P
8	8	1	1

IF THESE ARE CORRECT TYPE GO: GO

ENTER AN INDICATOR NAME, LIMITED TO 10 CHARACTERS: PLO WARNS
SELECT THE NUMBER OF THE EVENT WHICH "PLO WARNS" AFFECTS:

1) EVACUATION
2) HOSTILITYS
3) ISRAEL ACT
4) ELECTIONS
5) SYRIA

SELECTION: 4
ENTER THE LIKELIHOOD RATIO FOR THE OUTCOMES OF ELECTIONS AFTER PLO WARNS:

YES+S	YES-S	NO/S	NO/P
1	1	1	7

IF THESE ARE CORRECT TYPE GO: GO

ENTER AN INDICATOR NAME, LIMITED TO 10 CHARACTERS: EXT FIGHT
SELECT THE NUMBER OF THE EVENT WHICH "EXT FIGHT" AFFECTS:

1) EVACUATION
2) HOSTILITYS
3) ISRAEL ACT
4) ELECTIONS
5) SYRIA

SELECTION: 2
ENTER THE LIKELIHOOD RATIO FOR THE OUTCOMES OF HOSTILITYS AFTER EXT FIGHT:

DECR	SQ	BEIRT	CNTRY
1	1	3	5

IF THESE ARE CORRECT TYPE GO: GO

ENTER AN INDICATOR NAME, LIMITED TO 10 CHARACTERS:

The system will now respond by calculating and displaying the conditioned probabilities of the outcomes of EVACUATION (with none of the indicators activated). It will then ask the user whether a display of the influence diagram is desired. If the user responds negatively, the same

display may be requested later by using the "Display Diagram" option available in the primary menu (see Figure 6-2, Section 6.2.3). This process is shown in Figure 6-5.

DO YOU WISH TO INCLUDE ANY ADDITIONAL INDICATORS (YES OR NO)? NO

CONDITIONED PROBABILITIES OF EVACUATION:

NONE - 53
P-300 - 3
P-2K - 14
NP-2K - 17
NP-6K - 14

DO YOU WANT TO DISPLAY THE INFLUENCE DIAGRAM (YES OR NO)? NO

Figure 6-5
DISPLAY OF THE CONDITIONED PROBABILITIES

The system will now display the primary menu and await further user instructions.

6.1.3 Using the INFER software to view the example problem - After the model has been structured and the computer has returned to the primary menu shown in Figure 6-2, the user may view or revise the results as desired. However, the user should first save the results to avoid the loss of the model should a computer or electrical failure occur. The user should therefore select "Save Model" and return the carriage. The computer displays the names of the models already available and asks the user for the name of the new model. If the specified name is the same as an existing name, the computer will request confirmation before replacing the old model. Otherwise, the computer will add the new name and model to its list. Figure 6-6 shows a possible format of this interchange.

```
MODELS CURRENTLY AVAILABLE:
     1)  RECCE
     2)  WARSAW
     3)  DEMO
ENTER THE NEW MODEL NAME:  DEMO
A MODEL BY THIS NAME EXISTS.
DO YOU WISH TO REPLACE IT (YES OR NO)?  NO
ENTER THE NEW MODEL NAME:  EVACUATION
IF "EVACUATION" IS CORRECT, PLEAST TYPE GO:  GO
```

Figure 6-6
SAVING A MODEL

After the model has been saved, the system will return to the primary menu. Selecting the "Display Results" option produces an output similar to that shown in Figure 6-5. But, instead of offering the user the option of viewing the influence diagram, the system simply returns to the primary menu.

The user may now wish to display the inference model. This is achieved by selecting "Display Inference Model" option. When this option is selected, a menu of the various events appears, as shown in Figure 6-7.

```
SELECT THE NUMBER OF THE EVENT TO BE DISPLAYED.
     1)  EVACUATION
     2)  HOSTILITYS
     3)  ISRAEL ACT
     4)  ELECTIONS
     5)  SYRIA
SELECTION:
```

Figure 6-7
MENU OF EVENTS

Upon selecting any specific event, the influencing events and the assessed probabilities are listed. Also listed (in parentheses, in the format shown in Figure 6-8) are the assessed or conditioned probabilities of the outcomes of the influencing events. Figures 6-8A through 6-8E show possible outputs for the five events in this model.

SELECTION: 1

EVACUATION
INFLUENCING EVENTS:
1) HOSTILITYS
2) ISRAEL ACT

1	2	PROB	NONE	P-300	P-2K	NP-2K	NP-6K
DECR	INVAD	(3)	10	5	25	30	30
DECR	NOINVAD	(13)	100	0	0	0	0
SQ	INVAD	(4)	10	5	25	30	30
SQ	NOINVAD	(18)	80	5	5	10	0
BEIRT	INVAD	(5)	5	0	10	40	45
BEIRT	NOINVAD	(28)	50	5	20	15	10
CNTRY	INVAD	(4)	5	0	10	40	45
CNTRY	NOINVAD	(24)	40	0	20	20	20
MARGINAL PROBS:			53	3	14	17	14

RETURN CARRIAGE TO CONTINUE

Figure 6-8A
VIEWING EVACUATION

SELECTION: 2

HOSTILITYS
INFLUENCING EVENTS:
1) ELECTIONS

1	PROB	DECR	SQ	BEIRT	CNTRY
YES+S	(40)	30	20	30	20
YES-S	(10)	20	30	30	20
NO/S	(20)	5	25	40	30
NO/P	(30)	5	20	35	40
MARGINAL PROBS:		16	22	33	28

RETURN CARRIAGE TO CONTINUE

Figure 6-8B
VIEWING HOSTILITYS

SELECTION: 3

ISRAEL ACT
INFLUENCING EVENTS:
1) SYRIA

1	PROB	INVAD	NOINV
NORTH	(92)	10	90
SOUTH	(8)	90	10
MARGINAL PROBS:		16	84

RETURN CARRIAGE TO CONTINUE

Figure 6-8C
VIEWING ISRAEL ACT

SELECTION: 4

ELECTIONS
INFLUENCING EVENTS: NONE SPECIFIED

	YES+S	YES-S	NO/S	NO/P
MARGINAL PROBS:	40	10	20	30

RETURN CARRIAGE TO CONTINUE

Figure 6-8D
VIEWING ELECTIONS

SELECTION: 5

SYRIA
INFLUENCING EVENTS:
1) HOSTILITYS

1	PROB	NORTH	SOUTH
DECR	(16)	95	5
SQ	(22)	95	5
BEIRT	(33)	95	5
CNTRY	(28)	85	15
MARGINAL PROBS:		92	8

RETURN CARRIAGE TO CONTINUE

Figure 6-8E
VIEWING SYRIA

After viewing the inference model, the user may decide that it requires editing. If so, the "Edit the Model" option should be selected, and the system will present the user the choice of editing the diagram or editing the indicators. Figure 6-9 shows this process.

```
SELECT THE NUMBER OF THE DESIRED OPTION
     1)  CREATE NEW MODEL
     2)  DISPLAY RESULTS
     3)  DISPLAY INFERENCE MODEL
     4)  EDIT THE MODEL
     5)  RESET INDICATORS
     6)  SAVE MODEL
     7)  LOAD MODEL
SELECTION:  4

SELECT THE NUMBER OF THE DESIRED OPTION
     1)  EDIT THE DIAGRAM
     2)  EDIT INDICATORS
SELECTION:  1
```

Figure 6-9
ENTERING THE DIAGRAM EDITING MODE

Selecting "Edit the Diagram" causes a new menu (similar to the menu shown in Figure 6-7) to be displayed. The user may then select the set of probabilities to be edited. Figure 6-10 gives an example of how editing is performed. (Later displays in this document do not reflect changes positioned in this figure.)

```
SELECT THE NUMBER OF THE EVENT TO BE EDITED
     1)  EVACUATION
     2)  HOSTILITYS
     3)  ISRAEL ACT
     4)  ELECTIONS
     5)  SYRIA
SELECTION:  5

SYRIA
INFLUENCING EVENTS:
     1)  HOSTILITYS

                1          NORTH          SOUTH

          1)  DECR          95              5
          2)  SQ            95              5
          3)  BEIRT         95              5
          4)  CNTRY         85             15

ENTER THE NUMBER OF THE LINE TO BE EDITED:  3

                           NORTH          SOUTH

          BEIRT             9              1
          NORMALIZED:      90             10
IF THESE ARE CORRECT TYPE GO:  GO

ENTER THE NUMBER OF THE LINE TO BE EDITED:
```

Figure 6-10
EDITING THE DIAGRAM

Returning the carriage at this point (without entering a number) returns the user to the menu shown at the beginning of Figure 6-10. The assessments of relative likelihood can be changed by using "Edit the Diagram," but the structure of the model cannot. In fact, the only way to alter the model's structure (other than by the use of indicators) is to create a wholly new structure by using "Create New Model."

Instead of editing the diagram, the user may wish to edit the indicators. Selecting the option "Edit Indicators" causes the computer to display another menu containing the options "Change Likelihoods" and "Add Indicators."

Selecting "Change Likelihoods" causes the computer to display a menu of the indicators and the user must select the indicator requiring editing. The computer then allows the user to alter the previously assessed likelihood ratio. Figure 6-11 gives an exemplary format for this procedure. (Later displays in this section do not reflect changes positioned in this figure.)

```
SELECT THE NUMBER OF THE OPTION DESIRED.
     1)  EDIT THE DIAGRAM
     2)  EDIT INDICATORS
SELECTION:  2

SELECT THE NUMBER OF THE OPTION DESIRED.
     1)  CHANGE LIKELIHOODS
     2)  ADD INDICATORS
SELECTION:  1

SELECT THE NUMBER OF THE INDICATOR TO BE EDITED:
     1)  ISR THREAT
     2)  SYR WARNS
     3)  ELEC PLAND
     4)  PLO WARNS
     5)  EXT FIGHT
SELECTION:  3

ELEC PLAND:  AFFECTS "ELECTIONS"

                        YES+S    YES-S    NO/S    NO/P
CURRENT LIKELIHOODS:      8        8        1       1
NEW LIKELIHOODS:         10        6        1       1

IF THESE ARE CORRECT TYPE GO:  GO

SELECT THE NUMBER OF THE INDICATOR TO BE EDITED:
     1)  ISR THREAT
     2)  SYR WARNS
     3)  ELEC PLAND
     4)  PLO WARNS
     5)  EXT FIGHT
SELECTION:
```

Figure 6-11
EDITING THE LIKELIHOOD RATIOS OF THE INDICATORS

Instead of editing the indicators already present in the model, the user may choose to add an entirely new indicator to the model. This is done by selecting the "Add Indicator" option. This option results in the same computer prompts as appeared during the inputting of the indicators at the end of Section 6.1.2.

After the additional indicators have been designated, the user may wish to activate them. This is done by using the "Reset Indicators" option in the primary menu. This option allows the user to "turn on" the indicators to see the implications of the model should the indicated event occur. (The same option allows the user to turn off the indicators once the hypothesizing is complete.)

Selecting "Reset Indicators" causes the computer to display a menu of the available indicators. Next to the names of the indicator appears the word "ON" or the word "OFF," indicating whether or not the indicator has been activated. Selecting a specific indicator from this menu resets the indicator from ON to OFF or from OFF to ON, depending on its original status. Figure 6-12 shows the process after "Reset Indicators" is selected.

```
SELECT THE NUMBER OF THE INDICATOR TO BE RESET.
     1)  ISR THREAT (OFF)
     2)  SYR WARNS (OFF)
     3)  ELEC PLAND (OFF)
     4)  PLO WARNS (OFF)
     5)  EXT FIGHT (OFF)
SELECTION:  1
SELECT THE NUMBER OF THE INDICATOR TO BE RESET.
     1)  ISR THREAT (ON)
     2)  SYR WARNS (OFF)
     3)  ELEC PLAND (OFF)
     4)  PLO WARNS (OFF)
     5)  EXT FIGHT (OFF)
SELECTION:
```

Figure 6-12
RESETTING THE INDICATORS

Once the desired indicators are reset, the user may wish to view the results. This is done by selecting "Display Results" after resetting the indicators. Figures 6-13A through 6-13F show the altered results if various indicators are activated.

```
CONDITIONED PROBABILITIES OF EVACUATION
          NONE      35
          P-300      2
          P-2K      15
          NP-2K     24
          NP-6K     24

RETURN CARRIAGE TO CONTINUE
```

Figure 6-13A
RESULTS WITH ISR THREAT ACTIVATED

```
CONDITIONED PROBABILITIES OF EVACUATION
          NONE      48
          P-300      3
          P-2K      14
          NP-2K     19
          NP-6K     17

RETURN CARRIAGE TO CONTINUE
```

Figure 6-13B
RESULTS WITH SYR WARNS ACTIVATED

```
CONDITIONED PROBABILITIES OF EVACUATION
          NONE      57
          P-300      3
          P-2K      13
          NP-2K     15
          NP-6K     12

RETURN CARRIAGE TO CONTINUE
```

Figure 6-13C
RESULTS WITH ELEC PLAND ACTIVATED

```
CONDITIONED PROBABILITIES OF EVACUATION
          NONE      48
          P-300      3
          P-2K      15
          NP-2K     18
          NP-6K     16

RETURN CARRIAGE TO CONTINUE
```

Figure 6-13D
RESULTS WITH PLO WARNS ACTIVATED

```
CONDITIONED PROBABILITIES OF EVACUATION
          NONE      42
          P-300      2
          P-2K      17
          NP-2K     20
          NP-6K     19

RETURN CARRIAGE TO CONTINUE
```

Figure 6-13E
RESULTS WITH EXT FIGHT ACTIVATED

```
CONDITIONED PROBABILITIES OF EVACUATION
          NONE      18
          P-300      1
          P-2K      14
          NP-2K     32
          NP-6K     35

RETURN CARRIAGE TO CONTINUE
```

Figure 6-13F
RESULTS WITH ALL INDICATORS EXCEPT
ELEC PLAND ACTIVATED

Now that the user has viewed the results after revision and with various indicators activated, it may be desirable to save the new version of the model. This is done by once again selecting the "Save Model" option and replacing the current version of EVACUATION by the revised version.

Finally, the user may wish to view or edit another model; if so, that model must be loaded into the system by using the "Load Model" option in the primary menu. The user may then perform all the viewing and revising operations on this previously built model that were performed on the EVACUATION model. Figure 6-14 shows the loading process after "Load Model" is selected.

```
SELECT THE NUMBER OF THE MODEL TO BE LOADED
     1)  RECCE
     2)  WARSAW
     3)  DEMO
     4)  EVACUATION
SELECTION:  2
```

Figure 6-14
MODEL LOADING PROCESS

The model will then be loaded automatically by the system and will be available for immediate use.

7.0 ABRIDGED USER'S MANUAL

This section is designed for the user who is already familiar with INFER. It describes the essential elements of the probability assessment problem and discusses how these are molded into an INFER model.

7.1 Structuring the Problem

Every probability assessment problem appropriate for INFER includes the following elements:

- o terminal event (the key uncertainty) with several possible outcomes;
- o a set of intermediate events on which the key uncertainty depends, or on which the influencing events depend; and
- o a set of unconditioned events with several possible outcomes, the probabilities of which are known or can be directly assessed.

Assessments which must be made include:

- o the conditional probabilities of any event outcome, dependent on the outcome of all conditioning events; and
- o the probabilities of all unconditioned events.

In addition, events may be included in the model (known as indicators) which, if they occur, will change the probabilities of the outcomes of any specific event in a predictable way. Inclusion of these requires assessments to be

made concerning the likelihood of which of the various outcomes of the conditioned event should most give rise to the indicator.

Once these elements are identified and the assessments prepared, the user is ready to use the program.

7.2 Options Available in INFER

Once the INFER system is loaded into the computer, a menu of options will be displayed to the user. This menu contains the following options:

- Create New Model
- Display Results
- Display Inference Model
- Edit The Model
- Reset Indicators
- Load Model
- Save Model

Selecting "Create New Model" allows the user to create an altogether new model to solve a new probability assessment problem. This option is explained in Section 7.3.

Selecting "Display Results" causes the computer to display the conditioned probability of each of the possible outcomes of the terminal event.

Selecting "Display Inference Model" allows the user to select an event to be displayed. The conditioned probabilities of the outcomes of that event and all conditioning events are displayed, as is the conditional probability matrix.

Selecting "Edit the Model" allows the user either to edit the influence diagram itself or to edit the indicators. Editing the influence diagram amounts to changing any of the assessed conditional (or unconditioned) probabilities whereas editing the indicators allows the user to change the likelihood vector of any existing indicator or to add an altogether new indicator to the model.

Selecting "Reset Indicators" permits the user to activate or deactivate whatever indicators have been previously attached to the influence diagram.

Selecting "Load Model" allows the user to load a previously existing model from the model library into the computer. Selecting "Save Model" allows the user to save a newly created or edited model in the model library.

7.3 Structuring the Influence Diagram Using INFER

To structure the model, the user must load the INFER software program and select the "Create New Model" option. The user will be asked to enter the name of the event of interest, the key uncertainty. The computer will then ask for the names of the events influencing the key uncertainty, the names of any events influencing the newly named events, and so on, continuing until the user has made each event dependent upon zero, one, or two other events.

After the user has completely outlined the pattern of influence, the system will request the names of the possible outcomes of each event, beginning with those events which depend on no other events. The system then requests the conditional probability of each outcome, dependent on specific outcomes of influencing events where necessary.

When this process is completed, the system will ask the user whether the model includes any indicators. A positive response will cause the system to request the name of the first indicator and the name of the event which the indicator directly affects. The likelihood vector related to the possible outcomes of the event influenced by the indicator is the next input. The system will then give the user the opportunity to identify additional indicators. Once the user has indicated that no other indicators exist, the computer will automatically display the model results before returning to the primary menu. The user should immediately select "Save Model" to permanently store the model, avoiding the possible accidental loss of the model through human error or computer malfunction.